Appendix C. Bicycle Level of Service Methodology and Summary of Results

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Introduction

A comprehensive roadway inventory was an important component of the background analysis for the District of Columbia Bicycle Master Plan. Field measurements were taken on 406 miles of major collector and arterial streets in the District in early 2003. This accounts for about 45 percent of all DC streets. Roadway lane and shoulder width, speed limit, pavement condition, and on-street parking were collected and used in the scientifically-calibrated Bicycle Level of Service (Bicycle LOS) Model to evaluate the comfort of bicyclists on roadway segments. Bicycle Level of Service results were one of several sources of information used to select the bicycle route network. The Level of Service Methodology and a summary of the LOS analysis for DC streets are provided below.

Background

Level of Service (LOS) is a framework that transportation professionals use to describe existing conditions (or suitability) for a mode of travel in a transportation system. The traffic planning and engineering discipline has used LOS models for motor vehicles for several decades. Motor vehicle LOS is based on average speed and travel time for motorists traveling in a particular roadway corridor. In the 1990s, new thinking and research contributed to the development of methodologies for assessing levels of service for other travel modes, including bicycling, walking, and transit. Specific methodologies for bicycle level of service have been developed and used by a number of cities, counties, and states around the U.S. since the mid-1990s. This Plan adopts the Bicycle Level of Service (Bicycle LOS) Model assessment method.

When considering level of service in a multi-modal context, it is important to note that LOS measures for motor vehicles and bicycles are based on different criteria and are calculated on different inputs. Motor vehicle LOS is primarily a measure of speed, travel time, and intersection delay. Bicycle LOS is a more complex calculation, which represents the level of comfort a bicyclist experiences in relation to motor vehicle traffic.

Bicycle Level of Service Model

The *Bicycle Level of Service Model (Bicycle LOS Model)* is an evaluation of bicyclist perceived safety and comfort with respect to motor vehicle traffic while traveling in a roadway corridor. It identifies the quality of service for bicyclists or pedestrians that currently exists within the roadway environment.

The statistically calibrated mathematical equation entitled the *Bicycle LOS Model*[1] *(Version 2.0)* is used for the evaluation of bicycling conditions in shared roadway environments. It uses the same measurable traffic and roadway factors that transportation planners and engineers use for other travel modes. With statistical precision, the *Model* clearly reflects the effect on bicycling suitability or "compatibility" due to factors such as roadway width, bike lane widths and striping combinations, traffic volume, pavement surface condition, motor vehicle speed and type, and on-street parking.

The *Bicycle Level of Service Model* is based on the proven research documented in *Transportation Research Record 1578* published by the Transportation Research Board of the National Academy of Sciences. It was developed with a background of over 150,000 miles of evaluated urban, suburban, and rural roads and streets across North America. Many urban planning agencies and state highway departments are using this established method of evaluating their roadway networks. The Virginia Department of Transportation is using the *Bicycle LOS Model* in both the Richmond and Northern

[1]Landis, Bruce W. et.al. "Real-Time Human Perceptions: Toward a Bicycle Level of Service" *Transportation Research Record 1578*, Transportation Research Board, Washington, DC 1997.

Virginia regions. The model has also been applied in Anchorage AK, Baltimore MD, Birmingham AL, Buffalo NY, Gainesville FL, Houston TX, Lexington KY, Philadelphia PA, Sacramento CA, Springfield MA, Tampa FL, Washington, DC, and by the Delaware Department of Transportation (DelDOT), Florida Department of Transportation (FDOT), New York State Department of Transportation (NYDOT), Maryland Department of Transportation (MDOT) and many others.

Widespread application of the original form of the *Bicycle LOS Model* has provided several refinements. Application of the *Bicycle LOS Model* in the metropolitan area of Philadelphia resulted in the final definition of the three effective width cases for evaluating roadways with on-street parking. Application of the *Bicycle LOS Model* in the rural areas surrounding the greater Buffalo region resulted in refinements to the "low traffic volume roadway width adjustment". A 1997 statistical enhancement to the *Model* (during statewide application in Delaware) resulted in better quantification of the effects of high speed truck traffic [see the $SP_t(1+10.38HV)^2$ term]. As a result, *Version 2.0* has the highest correlation coefficient ($R^2 = 0.77$) of any form of the *Bicycle LOS Model*.

Version 2.0 of the *Bicycle Level of Service Model (Bicycle LOS Model)* has been employed to evaluate collector and arterial roadways in the District of Columbia. Its form is shown below.

$$\textbf{Bicycle LOS} = a_1 \ln(Vol_{15}/L_n) + a_2 SP_t(1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4(W_e)^2 + C$$

Where:

Vol_{15} = Volume of directional traffic in 15 minute time period

$Vol_{15} = (ADT \times D \times K_d) / (4 \times PHF)$

where:

ADT	=	Average Daily Traffic on the segment or link
D	=	Directional Factor (assumed = 0.565)
K_d	=	Peak to Daily Factor (assumed = 0.1)
PHF	=	Peak Hour Factor (assumed = 1.0)

L_n = Total number of directional *through* lanes

SP_t = Effective speed limit

$SP_t = 1.1199 \ln(SP_p - 20) + 0.8103$

where:

SP_p = Posted speed limit (a surrogate for average running speed)

HV = percentage of heavy vehicles (as defined in the 1994 Highway Capacity Manual)

PR_5 = FHWA's five point pavement surface condition rating

W_e = Average effective width of outside through lane:

where:

$W_e = W_v - (10 \text{ ft} \times \% \text{ OSPA})$	and $W_l = 0$
$W_e = W_v + W_l(1 - 2 \times \% \text{ OSPA})$	and $W_l > 0$ & $W_{ps} = 0$
$W_e = W_v + W_l - 2(10 \times \% \text{ OSPA})$	and $W_l > 0$ & $W_{ps} > 0$ and a bikelane exists

where:

W_t = total width of outside lane (and shoulder) pavement

OSPA = percentage of segment with occupied on-street parking

W_l = width of paving between the outside lane stripe and the edge of pavement

W_{ps} = width of pavement striped for on-street parking

W_v = Effective width as a function of traffic volume

and:

$$W_v = W_t \qquad \text{if ADT} > 4{,}000\text{veh/day}$$
$$W_v = W_t\,(2 - 0.00025 \times \text{ADT}) \qquad \text{if ADT} \leq 4{,}000\text{veh/day},$$

and if the street/ road is undivided and unstriped

a_1: 0.507 a_2: 0.199 a_3: 7.066 a_4: - 0.005   C: 0.760

(a_1 - a_4) are coefficients established by the multi-variate regression analysis.

The Bicycle LOS score resulting from the final equation is pre-stratified into service categories "A", "B", "C", "D", "E", and F", according to the ranges shown in Table 1, reflecting users' perception of the road segments level of service for bicycle travel. This stratification is in accordance with the linear scale established during the referenced research (i.e., the research project bicycle participants' aggregate response to roadway and traffic stimuli). The *Model* is particularly responsive to the factors that are statistically significant. An example of its sensitivity to various roadway and traffic conditions is shown on the following page.

Bicycle Level-of-Service Categories

LEVEL-OF-SERVICE	Bicycle LOS Score
A	≤ 1.5
B	> 1.5 and ≤ 2.5
C	> 2.5 and ≤ 3.5
D	> 3.5 and ≤ 4.5
E	> 4.5 and ≤ 5.5
F	> 5.5

The Model represents the comfort level of a hypothetical "typical" bicyclist. Some bicyclists may feel more comfortable and others may feel less comfortable than the Bicycle LOS grade for a roadway. A poor Bicycle LOS grade does not mean that bikes should be prohibited on a roadway. It suggests to a transportation planner that the road may need other improvements (in addition to shoulders) to help more bicyclists feel comfortable using the corridor.

Application

The *Bicycle LOS Model* is used by planners, engineers, and designers throughout the US and Canada in a variety of planning and design applications. Applications include:

1) Conducting a benefits comparison among proposed bikeway/roadway cross-sections

2) Identifying roadway restriping or reconfiguration opportunities to improve bicycling conditions

3) Prioritizing and programming roadway corridors for bicycle improvements

4) Creating bicycle suitability maps

5) Documenting improvements in corridor or system-wide bicycling conditions over time

Bicycle LOS Model Sensitivity Analysis

Bicycle LOS = $a_1 \ln (Vol_{15}/Ln) + a_2 SP_t(1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4 (W_e)^2 + C$

where:	a_1: 0.507	a_2: 0.199	a_3: 7.066	a_4: -0.005	C: 0.760
T-statistics:	(5.689)	(3.844)	(4.902)	(-9.844)	

Baseline inputs:

ADT	=	12,000 vpd	% HV	=	1	L	=	2 lanes
SP_p	=	40 mph	W_e	=	12 ft	PR_5	=	4 (good pavement)

	BLOS	% Change
Baseline BLOS Score (Bicycle LOS)	3.98	N/A

Lane Width and Lane striping changes

W_t	=	10 ft		4.20	6% increase
W_t	=	11 ft		4.09	3% increase
W_t	=	12 ft	- - (baseline average) - - - - - - -	3.98 - - - -	no change
W_t	=	13 ft		3.85	3% reduction
W_t	=	14 ft		3.72	7% reduction
W_t	=	15 ft	(W_l = 3 ft)	3.57 (3.08)	10%(23%) reduction
W_t	=	16 ft	(W_l = 4 ft)	3.42 (2.70)	14%(32%) reduction
W_t	=	17 ft	(W_l = 5 ft)	3.25 (2.28)	18%(43%) reduction

Traffic Volume (ADT) variations

ADT	=	1,000	Very Low	2.75	31% decrease
ADT	=	5,000	Low	3.54	11% decrease
ADT	=	12,000	Average - (baseline average) - -	3.98 - - - - -	no change
ADT	=	15,000	High	4.09	3% increase
ADT	=	25,000	Very High	4.35	9% increase

Pavement Surface conditions

PR_5	=	2	Poor	5.30	33% increase
PR_5	=	3	Fair	4.32	9% reduction
PR_5	=	4 - -	Good - (baseline average) - - -	3.98 - - - -	no change
PR_5	=	5	Very Good	3.82	4% reduction

Heavy Vehicles in percentages

HV	=	0	No Volume	3.80	5% decrease
HV	=	1 - - -	Very Low - (baseline average) - -	3.98 - - - - - -	no change
HV	=	2	Low	4.18	5% increase
HV	=	5	Moderate	4.88	23% increase[a]
HV	=	10	High	6.42	61% increase[a]
HV	=	15	Very High	8.39	111% increase[a]

[a] Outside the variable's range (see Reference *(1)*)

District of Columbia Bicycle LOS Results

Analysis of the major collector and arterial streets in the District of Columbia found that about 32 percent of the study network received above average grades of A, B, or C on an A (best) to F (worst) grading scale (see Exhibit 1). Streets with lower traffic volumes and bicycle lanes tended to have the highest Bicycle LOS grades. Most of the downtown streets and major arteries between downtown and the suburbs had grades of D or lower.

Exhibit 1. Bicycle Level of Service Results

Bicycle Level of Service	Miles	% of Miles with BLOS
A	17.8	4.4%
B	19.9	4.9%
C	91.7	22.5%
D	188.1	46.2%
E	80.5	19.8%
F	8.9	2.2%
Total	**406.9**	**100%**
Not evaluated	745.4	

Note: 745 miles of DC roadways were not evaluated. These were either limited access roads (freeways) or local streets where conditions tend to already be good for bicycling.